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# *Indian Standard*
# GUIDE FOR DRAFTING OF PERFORMANCE SPECIFICATIONS FOR CORES OF TRANSFORMERS AND INDUCTORS FOR TELECOMMUNICATION

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# *Indian Standard*

# GUIDE FOR DRAFTING OF PERFORMANCE SPECIFICATIONS FOR CORES OF TRANSFORMERS AND INDUCTORS FOR TELECOMMUNICATION

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# *Indian Standard*
# GUIDE FOR DRAFTING OF PERFORMANCE SPECIFICATIONS FOR CORES OF TRANSFORMERS AND INDUCTORS FOR TELECOMMUNICATION

## 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 16 December 1976, after the draft finalized by the Magnetic Components and Ferrite Materials Sectional Committee had been approved by the Electronics and Telecommunications Division Council.

**0.2** This standard provides guidance for drafting of performance specifications and article sheets for magnetic cores, the subject of the specification being the core properties which may be of importance in the most common applications of these cores.

**0.3** This standard is based on IEC Pub 367-2 (1974) 'Cores for inductors and transformers for telecommunications: Part 2 Guide for the drafting of performance specifications', issued by the International Electrotechnical Commission.

**0.4** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

## 1. SCOPE

**1.1** This standard provides guidance for drafting of performance specifications and article sheets for magnetic cores made of magnetic oxides or metallic powders, and used in inductors and transformers for telecommunication equipment and electronic devices employing similar techniques.

**1.2** This standard shall be read in conjunction with IS : 7687-1974†.

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*Rules for rounding off numerical values (*revised*).

†Methods of measurement for cores for inductors and transformers for telecommunications.

## 2. TERMINOLOGY

**2.0** For the purpose of this standard, in addition to the definitions given in IS : 1885 (Part XII)-1966*, IS : 1885 (Part XXXI)-1971†, IS : 1885 (Part XLI)-1975‡, IS : 7616-1974§ and IS : 7687-1974||; the following definitions shall apply.

**2.1 Apparent Permeability** ($\mu_{app}$) — The inductance $L$ of a measuring coil when assembled in a specified position on a given core, divided by the inductance $L'$ of the same coil measured without the core:

$$\mu_{app} = \frac{L}{L'}$$

**2.2 Toroidal Permeability** ($\mu_{tor}$) — The relative permeability of a material, measured on a toroid of the material:

$$\mu_{tor} = \frac{C_1}{\mu_0} \cdot \frac{L - L'}{N^2} + 1$$

where

$L$ = inductance of the coil of $N$ turns on the core, and

$L'$ = inductance of the same coil without core.

NOTE — This term is deprecated on the ground that it does not refer to a magnetic property but rather to a method of measurement.

**2.3 Turns Factor** ($\alpha$) — The number of turns that a coil of specified geometry, placed on a given core in a specified position, should have to obtain unit inductance:

$$\alpha = \frac{N}{\sqrt{L}}$$

where

$N$ = number of turns on the specified measuring coil, and

$L$ = inductance of the measuring coil when placed on the core.

NOTE 1 — The use of this term is deprecated because this quantity is not compatible with SI units.

NOTE 2 — If the unit of inductance is a submultiple of henry (normally millihenry), this shall be stated.

**2.4 Inductance Factor** ($A_L$) — The inductance of a coil of specified geometry, placed on a given core in a specified position, divided by the square of the number of turns:

$$A_L = \frac{L}{N^2}$$

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*Electrotechnical vocabulary: Part XII Ferromagnetic oxide materials.

†Electrotechnical vocabulary: Part XXXI Magnetism.

‡Electrotechnical vocabulary: Part XLI Non-reciprocal electromagnetic components.

§Guide for calculation of the effective parameters of magnetic piece parts.

||Methods of measurement for cores for inductors and transformers for telecommunications.

where

$N$ = number of turns on the specified measuring coil, and

$L$ = inductance of the measuring coil when placed on the core.

NOTE 1 — This term is closely related to permeance ($\Lambda$) [IS:1885 (Part XXXI)-1971*]; the latter refers to the reluctance of a core while inductance factor refers to the core with a winding.

NOTE 2 — In principle $A_L$ may apply to the several forms of permeability defined in the Indian Standard, for example, amplitude permeability, but, unless otherwise specified, it should be assumed that it corresponds to the initial effective permeability.

**2.5 Hysteresis Core Constant** ($\eta_i$) — An expression of the hysteresis loss of a magnetic core operating in the Rayleigh region. It is equal to the tangent of the loss angle due to hysteresis divided by the product of the peak current ($\hat{i}$) and the square root of the inductance ($L$) of the measuring coil:

$$\eta_i = \frac{(\tan \delta)_h}{\hat{i}\sqrt{L}}$$

NOTE — The relation between the hysteresis material constant and the hysteresis core constant is:

$$\eta_i = \eta_B \sqrt{\frac{\mu_o \mu_e^3}{V_e}}$$

where

$\eta_B$ = hysteresis material constant [*see* IS : 1885 (Part XXXI)-1971*], and

$V_e$ = effective volume (*see* IS : 7616-1974†).

**2.6 Variability** — The changes in the magnetic properties of a material or magnetic circuit with time or with operating conditions, or both.

NOTE — Normally, variability refers more specifically to changes of permeability. Temperature dependence of permeability and disaccommodation are the most common examples of variability.

**2.7 Temperature Factor** ($\alpha_F$) — The negative of the change in the reluctivity (reciprocal of permeability) of a material due to change in temperature divided by that change in temperature:

$$\alpha_F = \frac{\dfrac{1}{\mu_\theta} - \dfrac{1}{\mu_{ref}}}{\theta - \theta_{ref}} = \frac{\mu_\theta - \mu_{ref}}{\mu_\theta \, \mu_{ref} \, (\theta - \theta_{ref})}$$

where $\mu_\theta$ ($\mu_{ref}$) is the effective permeability at temperature $\theta(\theta_{ref})$.

**2.8 Temperature Coefficient of Permeability** ($\alpha_\mu$) **(Effective Permeability** $\alpha_{\mu_e}$**) (Inductance** $\alpha_L$**)** — The fractional change of permeability

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*Electrotechnical vocabulary: Part XXXI Magnetism.

†Guide for calculation of the effective parameters of magnetic piece parts.

(effective permeability) (inductance) due to a change of temperature divided by that change in temperature:

$$\measuredangle_{\mu} = \frac{\mu_{\theta} - \mu_{ref}}{\mu_{ref}(\theta - \theta_{ref})} \; ; \; \measuredangle_{L} = \frac{L_{\theta} - L_{ref}}{L_{ref}\,(\theta - \theta_{ref})}$$

where $L_{\theta}$ ($L_{ref}$) is the inductance, and $\mu_{\theta}$ ($\mu_{ref}$) the effective permeability at temperature $\theta(\theta_{ref})$.

**2.9 Disaccommodation (*D*)** — The fractional decrease of permeability of a magnetic material measured at constant temperature over a given period of time:

$$D = \frac{\mu_1 - \mu_2}{\mu_1}$$

where $\mu_1$ and $\mu_2$ are successively measured values of relative permeability at the beginning and the end of the given period.

**2.10 Disaccommodation Coefficient (*d*)** — The disaccommodation after magnetic conditioning divided by the logarithm (to the base of 10) of the ratio of the time intervals between the cessation of that conditioning and the second and first measurement respectively:

$$d = \frac{D}{\log_{10} \frac{t_2}{t_1}}$$

where $D$ is the disaccommodation measured over the period of time between $t_1$ and $t_2$ after magnetic conditioning.

**2.11 Disaccommodation Factor (*D*F)** — A quantity obtained by dividing the disaccommodation coefficient by the relative permeability measured at the first measuring time:

$$D_F = \frac{d}{\mu_1}$$

**2.12 Magnetic Conditioning** — A treatment of a magnetic material or core to obliterate its magnetic history and to put it in a well-defined and reproducible magnetic state.

**2.13 Instability (*S*)** — The fractional change in permeability caused by a specified disturbance:

$$S = \frac{\mu_2 - \mu_1}{\mu_1}$$

where

$\mu_1$ = relative permeability immediately before the applied disturbance, and

$\mu_2$ = relative permeability at a specified time after the applied disturbance.

**2.14 Instability Factor ($S_F$)** — The instability divided by the relative permeability measured immediately before the application of the disturbance:

$$S_F = \frac{S}{\mu_1}$$

**2.15 Parallel Reactance Coefficient ($X_p/N^2$)** — The parallel reactance ($X_p$) of a coil of specified geometry, placed on a given core in a specified position, divided by the square of the number of turns. The parallel reactance is the reactive component of the impedance expressed in terms of parallel elements.

**2.16 Parallel Resistance Coefficient ($R_p/N^2$)** — The parallel resistance ($R_p$) of a coil of specified geometry, placed on a given core in a specified position, divided by the square of the number of turns. The parallel resistance is the resistive component of the impedance expressed in terms of parallel elements.

**2.17 Type of Core** — A type comprises cores having definite common features and manufactured by the same technology.

NOTE — Common features cover in general the core shape and the properties of the material used.

**2.18 Test** — A procedure followed in order to determine whether a particular requirement of a specification is met.

**2.19 Type (or Qualification) Test(s)** — The complete series of test(s) to be carried out on a number of specimens representative of the type, with the object of determining whether a particular manufacturer may be considered capable of making products meeting the specification.

**2.20 Type (or Qualification) Approval** — The decision by the proper authority that a particular manufacturer may be considered to be able to produce in reasonable quantities, the type meeting the specification.

**2.21 Quality Conformance Tests** — Tests carried out under the responsibility of the manufacturer to ensure that products accepted for delivery comply with the specification.

**2.22 Acceptance Tests** — Tests carried out on samples selected from a lot for the purpose of acceptance of the lot.

**2.23 Routine Test** — Tests carried out on each component to check the requirements which are likely to vary during production.

## 3. GENERAL INFORMATION

**3.1** For drafting performance specifications and article sheets for magnetic cores, data on any, or all, of the characteristics listed in the relevant clauses may be required (*see* **3** of IS : 7687-1974*).

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*Methods of measurement for cores for inductors and transformers for telecommunications.

**3.2** Since the values measured for certain characteristics depend upon the geometry and position of the measuring coil, this coil shall be specified in sufficient detail before agreement may be reached on the value of such characteristics.

**3.3** Where limits for core losses measured with a coil are stated in a specification, the coil losses shall be made negligible or a correction applied.

**3.4** Equations are given for basic SI units only. In specifications and article sheets, the following multiples or sub-multiples will normally be used:

| | |
|---|---|
| $\text{mm}^{-1}$ | for core factor $C_1$, |
| $\text{mm}^{-3}$ | for core factor $C_2$, |
| kHz | for frequency, |
| mH | for inductance, |
| nH | for inductance factor, |
| mT | for flux density, |
| mA | for current, and |
| kA/m | for magnetic field strength. |

**3.5** The following symbols shall be used in the formulae of this standard:

$t$ = time,
$\theta$ = temperature,
$L$ = self-inductance,
$\mu_o$ = magnetic constant, $0{\cdot}4\,\pi \times 10^{-6}$ H/m,
$\mu_r$ = relative permeability (*see* Note),
$\mu_i$ = initial permeability,
$\mu_e$ = effective permeability = $\dfrac{LC_1}{\mu_o N^2}$
$\mu_{rev}$ = reversible permeability,
$N$ = number of turns on the measuring coil,
$C_1$ and $C_2$ = core factors defined in IS : 7616-1974*,
$A_e$ = effective cross-sectional area, and
$\omega$ = angular frequency = $2\,\pi \times$ frequency of measuring current.

NOTE — In the case of qualified versions of permeability, such as initial permeability $\mu_i$, the relative quantity is meant, unless otherwise stated.

### 3.6 General Explanation on Measuring and Testing

**3.6.1** *Direct Measuring Methods* — The direct measuring methods allow the measurement of the characteristics of the cores directly and should therefore be used when comparing different cores made of different materials or by different manufacturers such as is done in the case of type tests.

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*Guide for calculation of the effective parameters of magnetic piece parts.

For these test methods, reference should be made to IS : 7687-1974*.

**3.6.2** *Indirect Measuring Methods* — The indirect measuring methods only allow the comparison of cores of the same construction and material made by the same manufacturer. Their use is therefore restricted to those cases where the correlation with the direct measuring methods has been established. After agreement between the manufacturer and the purchaser, they may be used for factory tests and for acceptance tests, if included in the relevant specification.

**3.6.3** *Number of Specimens*

**3.6.3.1** *General* — The number of specimens to be tested in any particular case depends upon the purpose of the testing and the accuracy to be achieved for the result.

**3.6.3.2** *Type tests* — In the case of type tests, the sample shall be representative of the range of values [sizes, $A_L$ values (*see* **5.2.1**), tolerances, etc] of the type under consideration.

The appropriate number of specimens to be tested shall be agreed upon between the purchaser and the manufacturer.

NOTE — Part of a full range, or individual values, may be subjected to type tests in order to gain limited type approval.

**3.6.3.3** *Failures* — This guide does not specify the number of permissible failures; this is considered to be the prerogative of the authority giving type approval, unless covered in the relevant specification.

**3.6.4** *Sub-division of the Characteristics* — The characteristics to be specified for the various types of cores are listed in **4** to **7**. They depend upon the general application of the core. These lists of characteristics are divided into two parts serving the following main purposes:

a) To state the minimum information on performance characteristics required in specifications for transformer and inductor cores, referred to as 'minimum information in core specifications'; and

b) To give guidance for further information which may be supplied by the manufacturer for the use of designers, referred to as 'additional information on cores'.

**3.6.4.1** In addition to these two categories, guidance on mechanical requirements may be given.

## 4. GENERAL RULES FOR THE DRAFTING OF PERFORMANCE SPECIFICATIONS

**4.1** Performance specifications shall be clear, unequivocal and as complete as possible. When they contain requirements for certain core properties, which shall be met, and also information which is only for the guidance of users, these two types of information shall be clearly separated.

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*Methods of measurement for cores for inductors and transformers for telecommunications.

Article sheets for core types for which a format has been established in **5** and subsequent clauses shall follow that format as far as it reasonably applies.

**4.2** Performance specifications shall contain at least the following information:

a) Authority responsible for the establishing of the specification;

b) Reference number and date of issue or issue number;

c) Scope containing a short description of the core, its intended application, etc;

d) Dimensional sketch;

e) Essential dimensions with tolerances;

f) Limit values (requirements) for the essential characteristics of the core;

g) Details on measuring methods and conditions for the essential characteristics, as far as required (for example, clamping force for cores consisting of more than one part);

h) Operating temperature range in °C, within which the core may be used without damage and within which the parameters related to this range stay within specified limits; and

j) Limiting values for any condition of use which is essential for maintaining the core properties.

**4.3** The requirements [*see* **4.2**(f)] shall, in principle, cover all characteristics listed as 'minimum information of core specifications' in the relevant clause of this standard. They may further cover some or all characteristics of the 'further information on cores' as appropriate. Additional characteristics may be added as required, but in that case the characteristics described in the relevant clause of this standard should be considered as preferred.

**4.4** For measuring methods, reference shall be made to IS : 7687-1974*. Additional information (such as measuring conditions not listed in IS : 7687-1974*) and unavoidable deviations from these test methods shall be unambiguously stated.

In those cases where the measuring frequency or frequencies for the characteristics to be specified are not dictated by the application or by other considerations, they should be chosen from the series 1, 3, 10, . . . , etc, kHz.

**4.5** When measurements at vanishingly low value of the flux density (for example, within the Rayleigh region) are specified, or implied (such as for initial permeability), the level of flux density shall be such that doubling of the peak effective flux density $\hat{B}_e$ causes a negligible change in measured value.

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NOTE — The peak effective flux density $\hat{B}_e$ in a core is calculated from:

$$\hat{B}_e = \frac{U\sqrt{2}}{\omega . N . A_e}$$

where U is the rms value of the sinusoidal voltage applied to the measuring coil.

**4.6** For all core types, information on the values of the effective parameters shall be considered in the category of additional information on cores.

**4.6.1** The core factors shall be calculated in accordance with IS : 7616-1974*. They are defined by the following:

$$C_1 = \sum \frac{l}{A} \text{ mm}^{-1} \text{ (\textit{see} Note)}$$

$$C_2 = \sum \frac{l}{A^2} \text{ mm}^{-3}$$

NOTE — Sometimes the permeance factor $c = \frac{\mu_o}{C_1}$ is used.

**4.6.2** The effective dimensions may be calculated as follows:

a) Effective area $A_e = \frac{C_1}{C_2}$

b) Effective length $l_e = \frac{C_1^2}{C_2}$

c) Effective volume $V_e = \frac{C_1^3}{C_2^2}$

## 5. CORES FOR TUNED TRANSFORMERS AND INDUCTORS

### 5.1 General

**5.1.1** This information specifically applies to cores without air gap or with relatively small air gap for transformers and inductors in which the reactance forms part of a resonant circuit. It is restricted to those geometries for which the characteristics listed in **5.2** and **5.3** are significant when measured in accordance with IS : 7687-1974†. This will not be the case, for example, for short rods used as cores in RF inductors.

**5.1.2** In addition to the items mentioned in this clause, the information covered in **4** shall also be considered when drafting performance specifications and article sheets for these types of cores.

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*Guide for calculation of the effective parameters of magnetic piece parts.

†Methods of measurement for cores for inductors and transformers for telecommunications.

**5.1.3** For cores with adjusting devices, the performance specification normally applies to cores without the adjuster.

Where explicitly stated, cores with adjuster shall meet the requirements of the specification both with the adjuster at any point in the specified range and with the adjuster removed, but taking into account the increase in effective permeability due to the presence of the adjuster. In this case, any core of a batch combined with any adjuster of an appropriate type should meet the specification.

NOTE — Throughout the adjustment range, the mechanical engagement of the adjuster shall be such that the stability of inductance is satisfactory at any point in the range. The outline dimensions for the core with adjusting device apply when the adjuster is anywhere within the adjustment range.

**5.1.4** For the definitions on inductance adjustment, *see* **10.2** of IS : 7687-1974*.

**5.2 Minimum Information in Core Specifications**

**5.2.1** *Inductance Factor — See* **7** of IS : 7687-1974*. The nominal value and tolerance of the initial inductance factor $A_L$ at 25°C shall be stated for a specified frequency. For cores with an adjusting device, the adjuster shall be removed when measuring this factor.

**5.2.2** *Residual and Eddy Current Losses—See* **11.4** of IS : 7687-1974*. The maximum value of the loss factor due to residual and eddy current losses in the core

$$\frac{(\tan\delta)_{r+F}}{\mu_e}$$

at 25°C shall be stated for two or more specified frequencies, preferably chosen from the standard frequencies (*see* **4.4**) depending on the frequency range of the core.

NOTE 1 — The residual and eddy current losses are assumed to be equal to the total core losses at, or extrapolated to, vanishingly low values of flux density (*see* **4.5**).

NOTE 2 — The product of the effective permeability and the quality factor corresponding to residual and eddy current losses, $\mu_e\,Q_{r+F}$ may be quoted instead of $\frac{(\tan\delta)_{r+F}}{\mu_e}$, the conversion being:

$$\frac{(\tan\delta)_{r+F}}{\mu_e} = \frac{1}{\mu_e\,Q_{(r+F)}}$$

**5.2.3** *Hysteresis Losses — See* **11.5** of IS : 7687-1974*. The maximum value of the hysteresis core constant $\eta_i$ or the tangent of the loss angle due to hysteresis $(\tan\delta)_h$, at 25°C shall be stated for a specified low frequency, preferably chosen from the standard frequencies (*see* **4.4**) depending on the frequency range of the core. Alternatively, the hysteresis material constant $\eta_B$ may be specified.

NOTE 1 — Conversion between $\eta_i$ and $(\tan\delta)_h$:

$$\eta_i = \frac{(\tan\delta)_h}{\hat{i}\sqrt{L}}$$

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*Methods of measurement for cores for inductors and transformers for telecommunications.

NOTE 2 — Conversion between $\eta_B$ and $(\tan\delta)_h$:

$$\eta_B = \frac{(\tan\delta)_h}{\mu_e \hat{B}_e}$$

where $\hat{B}_e$ is the effective peak value of flux density (*see* **4.5**).

NOTE 3 — For flux densities well below saturation (for example, within the Rayleigh region), the following approximate relation exists between the hysteresis losses and non-linear voltage distortion when sinusoidal current is passed through the coil:

$$\frac{E_3}{U_1} \approx 0{\cdot}6\ (\tan\delta)_h$$

where

$U_1$ = fundamental voltage applied to the measuring coil, and
$E_3$ = emf of third harmonic frequency generated by the core.

**5.2.4** *Disaccommodation* — *See* **8** of IS : 7687-1974*. The maximum value of the disaccommodation factor, or of the disaccommodation, at 25°C and over the following specified time intervals, shall be stated:

a) 10 to 100 minutes after magnetic conditioning, or
b) 24 to 48 hours after thermal conditioning.

**5.2.5** *Temperature Coefficient of Effective Permeability* — *See* **9** of IS : 7687-1974*. The maximum and minimum values of the temperature coefficient of initial effective permeability of the core over the specified temperature range shall be stated.

NOTE — For cores, such as pot cores, which may be delivered with a variety of different air gaps, it is desirable to specify the minimum and maximum temperature factor of the core when the only air gaps in the flux path are the residual air gaps due to the contact surfaces.

**5.2.6** *Range of Adjustment* (*Cores with Adjusting Device Only*) — *See* **10** of IS : 7687-1974*. The maximum inductance at the lower limit and the minimum inductance at the upper limit of the adjustment range (*see* **5.1.4**) shall be stated as a percentage of the inductance measured without adjuster, at 25°C and at the same temperature and frequency for which the inductance factor is stated.

**5.3 Additional Information on Cores**—*See also* **4.6**.

**5.3.1** *Effective Permeability* — *See* **7** of IS : 7687-1974*. The nominal value of the effective permeability at low flux density, at 25°C and for a specified frequency shall be stated.

**5.3.2** *Influence of a Static Magnetic Field* — *See* **15** of IS : 7687-1974*. A curve shall be given for each core type showing the inductance factor as a function of the static magnetomotive force.

**5.3.3** *Total Losses* — *See* **11** of IS : 7687-1974*. The total losses of the core shall be presented in graphical form as a function of the frequency with the flux density as a parameter. The coil geometry shall be stated.

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**5.4 Mechanical Requirements** — The following mechanical requirements shall be specified:

a) The maximum force which the core must be able to withstand, without damage, and the method of application of the force. (For cores consisting of more than one part, this force is normally related to the clamping force and applied in the same manner.)

b) For cores with an adjusting device, the maximum force which the fixed part must be able to withstand without damage or loosening from the core.

c) For screw type adjusting devices, the maximum torque exerted on the adjuster placed against the end stop, if any, which the adjusting device shall be able to withstand without damage and without loosening of the fixed part.

**5.5 Article Sheet Format** — The article sheet shall contain the following information.

**5.5.1** *Dimensions* — The dimensions shall be stated and shall be in accordance with the appropriate Indian Standards where applicable. For details for specific core types, see appropriate appendices of IS : 7687-1974*.

At least two of the five effective parameters and core constants, calculated in accordance with IS : 7616-1974†, shall be given, namely, $C_1$, $C_2$, $l_e$, $A_e$ and $V_e$ (*see* **4.6**). Most commonly used are $C_1$, $l_e$ and $A_e$.

**5.5.2** *General Information* — The following information shall be stated:

a) Reference to this standard;

b) Operating temperature range in °C [*see* **4.2**(h)]. Standard ranges are: −40°C to +70°C, −25°C to +70°C and +5°C to +55°C;

c) Details of marking; and

d) When desirable, an indication of the general material characteristics.

**5.5.3** *Measuring Conditions* — The following general conditions shall be stated in accordance with the clauses of IS : 7687-1974* referred to hereafter:

a) Standard atmospheric temperature for referee tests if other than 25°C (*see* **3.2** of IS : 7687-1974*),

b) Clamping force (*see* **4.3** of IS : 7687-1974*),

c) Details of measuring coils for inductance measurement and for loss measurement, or a reference to such details (*see* **7.2** and **11** of IS : 7687-1974*), and

d) Method for magnetic conditioning (*see* **6** of IS : 7687-1974*).

For additional details applicable to pot core types, *see* Appendix A.

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†Guide for calculation of the effective parameters of magnetic piece parts.

**5.5.4** *Performance Requirements for General Use* — The performance requirements shall be given in the following form. The crosses and dots represent values to be inserted. The units used shall be stated. The number of columns between that for 'No gaps' and that for 'Unit' shall be as appropriate:

| Initial effective permeability $\mu_e$ (*see* **5.3.1**) nominal | | No[1] gap | + | + | + | Unit |
|---|---|---|---|---|---|---|
| $A_L$ corresponding to $\mu_i$(*see* **5.2.1**) nominal | | + | + | + | + | + |
| Tolerance on $A_L$ (without adjusting device) | | | + | + | + | % |
| Range of adjustment (*see* **5.2.6**) | | | | | | |
| —adjuster No. .......... | *Min* | | + | + | + | % |
| | *Max* | | + | + | + | % |
| —adjuster No. .......... | *Min* | | + | + | + | % |
| | *Max* | | + | + | + | % |
| Measuring frequency ..........kHz | | | | | | |
| Applied voltage (rms) ..........mV | | | | | | |
| Temperature coefficient[2] of $\mu_e$ (*see* **5.2.5**) over the temperature range[3] | | | | | | |
| ..........to..........°C | *Min* | | + | + | + | + |
| | *Max* | | + | + | + | + |
| ..........to..........°C | *Min* | | + | + | + | + |
| | *Max* | | + | + | + | + |
| Alternatively | | | | | | |
| Temperature factor of $\mu_i$ over the temperature range | | | | | | |
| ..........to..........°C | *Min* | + | | | | $10^{-6}$/°C |
| | *Max* | + | | | | $10^{-6}$/°C |
| ..........to..........°C | *Min* | + | | | | $10^{-6}$/°C |
| | *Max* | + | | | | $10^{-6}$/°C |
| Measuring frequency..........kHz | | | | | | |
| Applied voltage (rms)..........mV | | | | | | |
| Disaccommodation factor (*see* **5.2.4**) | *Max* | + | | | | $10^{-6}$ |
| Residual and eddy current losses (*see* **5.2.2**) | *Max* | | | | | |
| $\frac{(\tan \delta)_{r+F}}{\mu_e}$ Max or ($\mu_e \times Q_{r+F}$) *Min* | | | | | | |
| —at measuring frequency..........kHz | | + | | | | |
| —applied voltage (rms)............mV | | | | | | |
| —at measuring frequency..........kHz | | + | | | | |
| —applied voltage (rms)............mV | | | | | | |
| Hysteresis material constant $\eta_B$ (*see* **5.2.3**) | *Max* | + | | | | + |
| Measuring frequency...........kHz | | | | | | |
| Applied voltage (rms): | | | | | | |
| first measurement ............mV | | | | | | |
| second measurement ..........mV | | | | | | |

1. Values in this column apply to cores in which the only air gaps in the flux paths are the residual air gaps due to the contact surfaces.

2. Alternatively, the total variation of $\mu_e$ over the temperature range(s) may be given.

3. When temperature coefficients are given over more than one temperature range or when the temperature range is split into two or more parts each with a different temperature coefficient assigned to it, these shall be separately stated.

**5.5.5** *Information on Performance Characteristics of Cores* — This information may be added at the discretion of the manufacturer or may be requested by the user. It may cover the following:

a) Average values of some of the characteristics given in **5.5.4**, and

b) Parameters of **5.2** and **5.3** not given in **5.5.4**.

The manufacturers, in their publications should include curves giving information on tan $\delta$ or $Q$ (including copper and other losses) for low flux density as a function of frequency for different coil constructions, which together cover the total frequency range of the core.

## 6. CORES FOR BROAD-BAND TRANSFORMERS

### 6.1 General

**6.1.1** This information specifically applies to cores without air gap or with relatively small air gap for transformers, the insertion loss of which should be low and constant over a relatively large frequency band; pulse transformers are not included. It is restricted to those geometries for which the characteristics listed in **6.2** and **6.3** are significant when measured in accordance with IS : 7687-1974*. This will not be the case, for example, for short rods used as cores in RF transformers.

**6.1.2** In addition to the information mentioned in **4**, the following items shall be considered when drafting performance specifications and article sheets for these types of cores.

### 6.2 Minimum Information in Core Specifications

**6.2.1** *Parallel Reactance Coefficient* — *See* **7** of IS : 7687-1974*. The minimum value of the effective parallel reactance per turn of a coil ($X_p/N^2$) within the operating temperature range shall be stated for a vanishingly low value of the flux density and for a specified low frequency, preferably chosen from the standard frequencies (*see* **4.4**) depending on the frequency range of the core.

NOTE 1 — The minimum inductance factor may be quoted for that frequency range where it is practically independent of frequency.

NOTE 2 — Conversion between parallel reactance coefficient and inductance factor is given below:

$$\frac{X_p}{N^2} = \omega A_L$$

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**6.2.2** *Total Losses—See* **11** of IS : 7687-1974*.

**6.2.2.1** *Parallel resistance coefficient* —The minimum value of the effective parallel resistance per turn of a coil ($R_V/N^2$) within the operating temperature range shall be stated for two or more specified frequencies, preferably chosen from the standard frequencies (*see* **4.4**) depending on the frequency range of the core, and for one or more values of the flux density.

NOTE — The parallel resistance coefficient is used when the insertion losses are of importance (telecommunication transformers).

**6.2.2.2** *Power loss* — As an alternative to **6.2.2.1**, the maximum value of the total losses $P$ (in watts) within the operating temperature range shall be stated for one or more specified frequencies, preferably chosen from the standard frequencies (*see* **4.4**) and for one or more relatively high values of flux density, depending upon the intended conditions of use of the core.

NOTE — The power loss is used when the heat development is of importance (power transformers).

**6.3 Additional Information on Cores**—*See also* **4.6**.

**6.3.1** *Dependence on Frequency and Flux Density*

**6.3.1.1** Curves shall be given showing typical values of the parallel reactance coefficient and of the parallel resistance coefficient as a function of frequency with the flux density as a parameter (*see* **6.2.1** and **6.2.2.1**).

**6.3.1.2** Curves shall be given showing typical values of power loss as a function of the flux density with the frequency as a parameter (*see* **6.2.2.2**).

**6.3.2** *Influence of a Static Magnetic Field — See* **15** of IS : 7687-1974*. Curves shall be given showing typical values of the parallel inductance factor corresponding to the incremental permeability as a function of the static magnetomotive force at various values of the air gap and, if necessary, at various values of frequency, incremental flux density and temperature. This may also be represented by the Hanna curve (*see* Note).

NOTE — A Hanna curve is the envelope to the curves representing:

$$\frac{LI^2}{V_e} \text{ as a function of } \frac{NI}{l_e}$$

where $I$ is the direct current.

The static magnetomotive force shall be expressed in amperes and the curves shall include information on the following two values of the air gap:

a) minimum air gap, and

b) such air gap that the parallel reactance coefficient without static field is 0·5 times that found at minimum air gap.

**6.3.3** *Non-linear Distortion — See* **12** of IS : 7687-1974*. The maximum value of the third harmonic material constant $\delta_B$ shall be stated for standard atmospheric conditions of testing and for a specified frequency.

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**6.3.4** *Hysteresis Losses* — *See* **11.5** of IS : 7687-1974*. The maximum value of the tangent of the loss angle due to hysteresis $(\tan \delta)_h$ shall be stated for standard atmospheric conditions of testing and at a specified low frequency, preferably chosen from the standard frequencies (*see* **4.4**) depending on the frequency range of the core. Alternatively, the material constant $\eta_B$ may be specified.

NOTE — Conversion between $\eta_B$ and $(\tan \delta)_h$:

$$\eta_B = \frac{(\tan \delta)_h}{\mu_e \hat{B}_e}$$

**6.3.5** *Normal Magnetization Curve* — The normal magnetization curve shall be given with the temperature as parameter.

**6.4 Mechanical Requirements** — The maximum force which the core must be able to withstand without damage, and the method of application of the force shall be stated. For cores consisting of more than one part, this force is normally related to the clamping force and applied in the same manner.

**6.5 Article Sheet Format** — The article sheet shall contain the following information.

**6.5.1** *Dimensions* — The dimensions shall be stated and shall be in accordance with the appropriate Indian Standards where applicable. For details on specific core types, see appropriate appendices of IS : 7687-1974*.

At least two of the five effective parameters and core constants, calculated in accordance with IS : 7616-1974† shall be given $C_1$, $C_2$, $l_e$, $A_e$ and $V_e$ (*see* **4.6**). Most commonly used are $C_1$, $l_e$ and $A_e$.

**6.5.2** *General Information* — The following information shall be stated:

a) Reference to this standard;
b) Operating temperature range in degrees Celsius [*see* **4.2** (h)]. Standard ranges are −40°C to +70°C, −25°C to +70°C and +5°C to +55°C;
c) Details of marking; and
d) When desirable, an indication of the general material characteristics.

**6.5.3** *Measuring Conditions* — The following general conditions shall be stated in accordance with the clauses of IS : 7687-1974* referred to hereafter:

a) Standard atmospheric temperature for referee tests if other than 25°C (*see* **3.2** of IS : 7687-1974*);
b) Clamping force (*see* **4.3** of IS : 7687-1974*);
c) Details of measuring coils for inductance measurement and, if

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†Guide for calculation of the effective parameters of magnetic piece parts.

applicable, for loss measurement, or a reference to such details (*see* **7.2** and **11** of IS : 7687-1974*); and

d) Method of magnetic conditioning (*see* **6** of IS : 7687-1974*).

For additional details applicable to specific core types, see the appropriate appendices of IS : 7687-1974*.

**6.5.4** *Performance Requirements for General Use* — The performance requirements shall be given in the following form. The crosses and dots represent values and units to be inserted.

The units shall be stated.

| | | Unit |
|---|---|---|
| Parallel reactance coefficient $\frac{X_p}{N^2}$ (*see* **6.2.1**) | .......... | $\Omega$ |
| over temperature range............°C to ..........°C | .......... | |
| —at measuring frequency..........kHz | | |
| rms voltage or voltage/turn | .......... | mV |
| corresponding to $\hat{B}_e$ (*see* **4.5**) | .......... | mT |
| alternatively | | |
| $A_L$ (*see* **5.2.1** and **6.2.1**) | .......... | + |
| —at measuring frequency..........kHz | | |
| rms voltage or voltage/turn | .......... | mV |
| corresponding to $\hat{B}_e$ (*see* **4.5**) | .......... | mT |
| Parallel resistance coefficient $\frac{R_p}{N^2}$ (*see* **6.2.2**) | .......... | |
| —at measuring frequency..........kHz | | |
| rms voltage or voltage/turn | .......... | mV |
| corresponding to $\hat{B}_e$ (*see* **4.5**) | .......... | mT |
| —at measuring frequency..........kHz | | |
| rms voltage or voltage/turn | .......... | mV |
| corresponding to $\hat{B}_e$ (*see* **4.5**) | .......... | mT |
| alternatively, when the power loss of importance total losses $P$ | .......... | + |
| —at measuring frequency..........kHz | | |
| rms voltage or voltage/turn | .......... | mV |
| corresponding to $\hat{B}_e$ (*see* **4.5**) | .......... | mT |
| —at measuring frequency..........kHz | | |
| rms voltage or voltage/turn | .......... | mV |
| corresponding to $\hat{B}_e$ (*see* **4.5**) | .......... | mT |

**6.5.5** *Information on Performance Characteristics of Cores* — This information may be added at the discretion of the manufacturer or may be requested by the user. It may cover:

a) Average values of some of the characteristics mentioned in **6.5.4**, and

b) Parameters of **6.3** not mentioned in **6.5.4**.

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## 7. CORES FOR PULSE TRANSFORMERS

**7.1 General** — This information specifically applies to cores for pulse transformers used in telecommunication, data handling and electronic equipment. Pulse transformers are classified in two categories, low power and high power.

NOTE 1 — Usually it is intended that low power pulse transformers will transmit a peak power of 300 watts or less and average power of 5 watts or less with a peak working voltage of 1 000 volts or less. Low power pulse transformers are normally designed to pulse shape requirements, high power pulse transformers to magnetization requirements.

NOTE 2 — Low power pulse transformers that use 'square loop' core material are not included in this guide.

**7.2 Object** — To establish uniform rules for specifying the core properties which may be of importance for the most common applications of these cores.

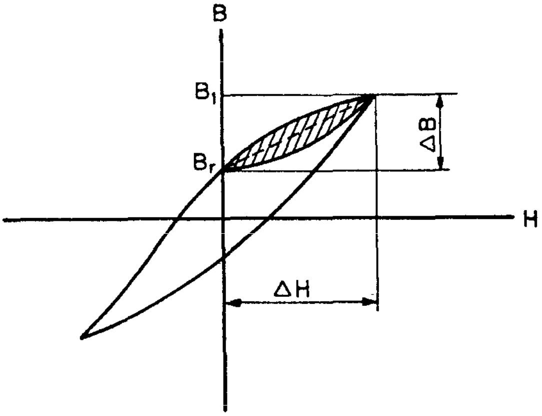
Where specific core properties are significant only in low power or high power pulse transformers, it will be identified as such.

**7.3 Terminology** — For the purpose of this section the following definitons shall apply.

**7.3.1** *Pulse Excitation*

**7.3.1.1** *Pulse excitation without reset* — A core which is energized by unidirectional pulses will operate over a minor hysteresis loop from $B_r$ to some higher value of $B$ (*see* Fig. 1).

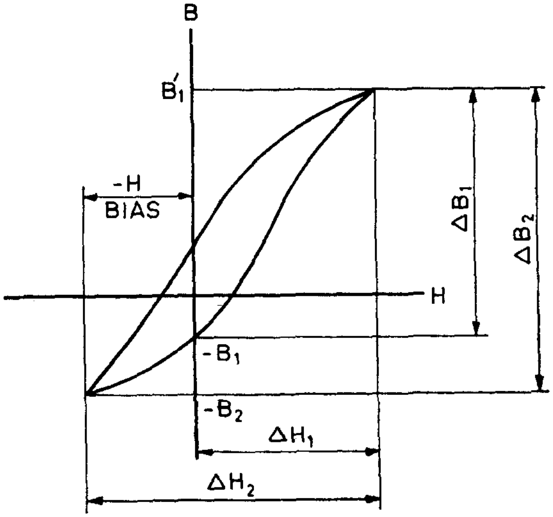
**7.3.1.2** *Pulse excitation with reset* — A core is alternately driven from some value of $-B$ to a $+B$, by a positive pulse. Reset may be accomplished by



$$\Delta B = B_1 - B_r$$

FIG. 1 *B-H* LOOP WITHOUT RESET

a negative pulse that will restore the core to its remanence condition of $-B_1$, or by a negative biasing field $-H$ to $-B_2$ (*see* Fig. 2).



$\triangle B_1 = B'_1 + | - B_1 |$ for pulse reset
$\triangle B_2 = B'_1 + | - B_2 |$ for bias reset

FIG. 2 *B-H* LOOP WITH RESET

**7.3.2** *Pulse Permeability* ($\mu_o$) — The ratio of $\triangle B$ to $\triangle H$ (*see* Fig. 1 and 2) and $\mu_\triangle = \frac{1}{\mu_o} \cdot \frac{\triangle B}{\triangle H}$.

**7.3.3** *Pulse Waveform* — A pulse waveform and its major characteristics are as shown and defined in Fig. 3.

**7.3.3.1** *Definitions of waveform parameters*

a) *Pulse Amplitude, U* — is the maximum absolute peak value of the pulse, excluding those portions considered unwanted or non-pertinent (for example, overshoot).

b) *Rise Time,* $t_r$ — is the time interval between the instants at which the instantaneous amplitude first reaches specified lower and upper limits of 10 percent and 90 percent of the pulse amplitude.

c) *Pulse Duration,* $t_d$ — is the time interval between the instants at which the instantaneous amplitude reaches 50 percent of the pulse amplitude.

d) *Fall Time*, $t_f$ — is the time interval between the instants at which the instantaneous amplitude last reaches specified upper and lower limits of 90 percent and 10 percent of the pulse amplitude.

e) *Droop* — The displacement voltage of the pulse amplitude as shown in Fig. 3. Droop is expressed in volts or as a percentage of the amplitude.

f) *Overshoot* — The amount by which the first maximum exceeds the pulse amplitude as shown in Fig. 3. Overshoot is expressed in volts or as a percentage of the pulse amplitude.

g) *Back Swing* — The maximum amplitude of the railing edge extending below the zero amplitude level. Back swing might be expressed in volts or as a percentage of the pulse amplitude.

h) *Return Back Swing* — The maximum amplitude of that portion of the trailing edge which has a polarity reversed to that of the back swing, and occurs later in time. It is expressed in volts or as a percentage of the pulse amplitude.

j) *Recovery Time* — The time interval between the time the trailing edge of the pulse first crosses a line representing 10 percent positive of the pulse amplitude and the last time the pulse shape crosses either a positive or negative line corresponding to 10 percent of the pulse amplitude.

**7.3.4** *Pulse Inductance*, $L_\Delta$ — The ratio of the applied voltage $U$ to the rate of change of the magnetizing current $i_m$:

$$L_\Delta = \frac{U}{\Delta i_m / \Delta t}$$

**7.3.5** *Pulse Inductance Factor*, $A_L$ — The value of pulse inductance factor of a core is:

$$A_{L\Delta} = \frac{L}{N^2}$$

**7.3.6** *Voltage-Time Product* $U.\ t_d$ — The product of the pulse amplitude voltage $U$ and the time $t_d$, where the magnetizing current reaches the admissible non-linearity.

NOTE — The admissible degree of non-linearity is not standardized and typically varies from $\frac{i_{m2}}{i_{m1}} = 1{\cdot}0$ to $1{\cdot}5$. Figure 4 shows the ratio $\frac{i_{m2}}{i_{m1}} = 1{\cdot}5$ at time $t_d$.

**7.4 Standard Pulse Repetition Rate** — If the number of pulses per second is not specified, it is recommended that it be chosen from 0·4 kHz and the series 1, 3, 10, etc, kHz.

## 7.5 Minimum Information in Core Specifications

**7.5.1** *Pulse Inductance Factor* — Limit values of the pulse inductance factor ($A_{L\Delta}$) at 25°C shall be stated for specified conditions, such as input pulse, test winding and pulse repetition rate.

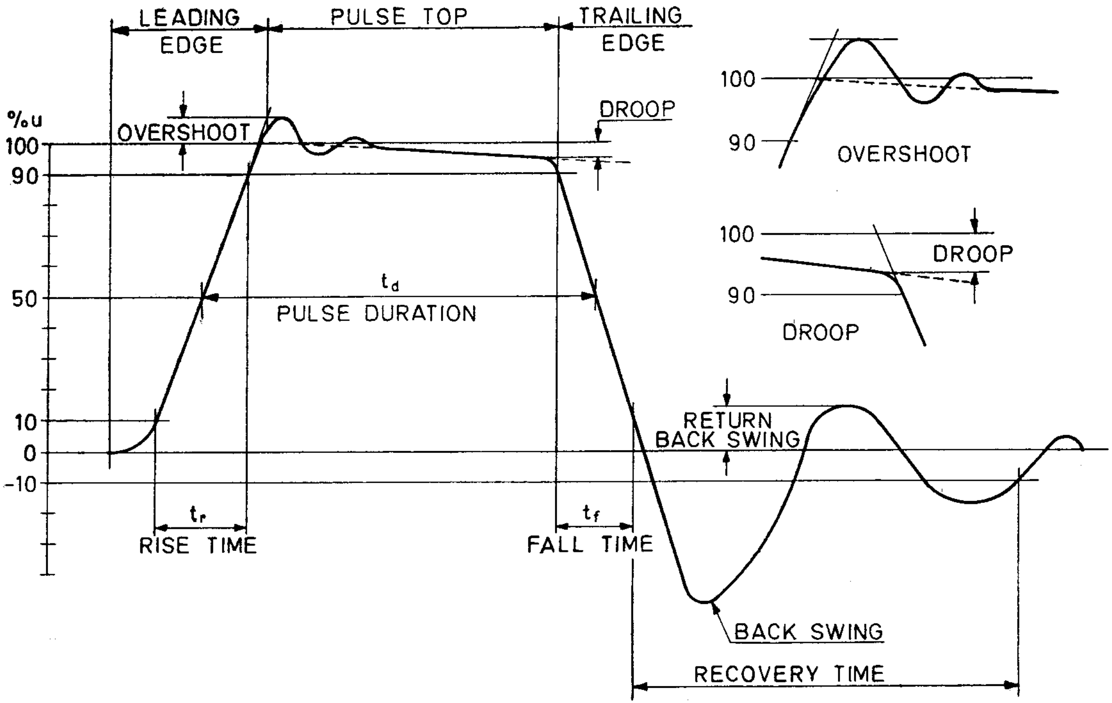


Fig. 3 Pulse Waveform

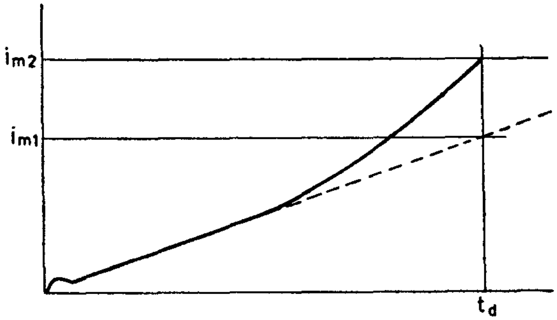


FIG. 4 NON-LINEARITY IN MAGNETIZING CURRENT

**7.5.2** *Magnetizing Current* — Limit values of the magnetizing current ($i_m$) at 25°C shall be stated for specified conditions, such as input pulse, test winding and pulse repetition rate.

NOTE—Although the pulse inductance factor ($A_{L\Delta}$) and magnetizing current ($i_m$) are interdependent, it is suggested in order to facilitate the transformer designer, that both parameters be specified for a given core.

**7.5.3** *Voltage-Time Product* — For a specific core the minimum $U-t_d$ product shall be stated. The ratio of the non-linear magnetizing current ($i_{m2}$) to the linear extrapolation ($i_{m1}$) shall be given.

**7.6 Additional Information on Cores** — For all core types, information on the values of the effective parameters shall be considered in the category of additional information on cores.

The core factors shall be calculated in accordance with IS : 7616-1974*. They are defined by:

$$C_1 = \sum \frac{l}{A} \text{ mm}^{-1} \text{ (see note)}$$

$$C_2 = \sum \frac{l}{A^2} \text{ mm}^{-3}$$

NOTE — Sometimes the permeance factor $c = \frac{\mu_0}{C_1}$ is used.

The effective dimensions may be calculated as:

a) Effective area $A_e = \frac{C_1}{C_2}$

b) Effective length $l_e = \frac{C^2{}_1}{C_2}$

c) Effective volume $V_e = \frac{C^3{}_1}{C^2{}_2}$

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*Guide for calculation of the effective parameters of magnetic piece parts.

**7.6.1** *Core Losses, $P_{\triangle}$* — The limit core loss values shall be presented in graphical form as a function of flux swing ($\triangle B$) with pulse duration, ($t_d$) repetition rate and temperature as parameters (*see* Fig. 5).

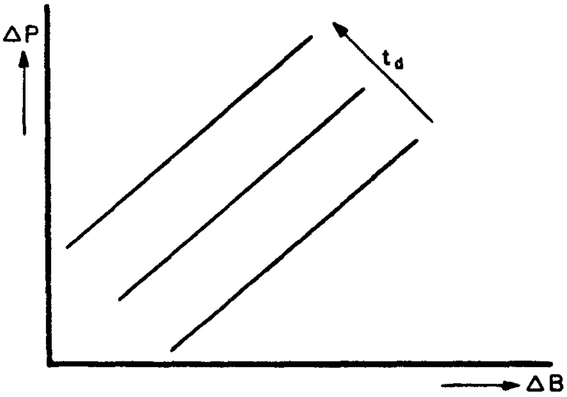

FIG. 5 CORE LOSSES

**7.6.2** *Inductance Factor, $A_L$*— The nominal value and tolerance of sinusoidal initial inductance factor shall be stated. Temperature and frequency should be specified.

**7.7 Mechanical Requirements** — The maximum force which the core must be able to withstand without damage, and the method of application of the force shall be stated. For cores consisting of more than one part, this force is normally related to the clamping force and applied in the same manner.

**7.8 Article Sheet Format** — Under consideration.

# APPENDIX A

( *Clause* 5.5.3 )

## ADDITIONAL DETAILS FOR POT CORES

### A-1. DIMENSIONS

**A-1.1** These shall be in accordance with IS : 6235-1971*.

### A-2. CLAMPING OF THE CORE

**A-2.1** Uniform distribution of the clamping force over the contact surfaces, without introducing bending stresses in the core parts, may be obtained by two rings of elastic, but not too soft material, having the following dimensions with the clamping force applied:

a) Inner diameter not less than the maximum inside diameter of the pot core ($d_2$ of IS : 6235-1971*); and

b) Outer diameter adapted to the outside diameter of the pot core ($d_1$ of IS : 6235-1971*).

In order to exert the clamping force on their outer ring, care shall be taken to place the elastic rings concentrically on the pot cores.

Before clamping, the core halves shall be centred on the centre holes, taking into account the indication, if any, of relative position of the core halves to each other. As far as there is still a possibility of relative movement, the position of maximum inductance shall be taken.

### A-3. MEASURING COILS

**A-3.1** No international agreement has been reached on measuring coils for pot cores.

### A-4. MECHANICAL TESTING

**A-4.1 Compression Load Test** — A force twice the clamping force shall be applied to the outer ring of the pot core for 1 minute. This force shall be uniformly distributed over the contact surfaces by means of the two rings as described in **A-2** above.

**A-4.2 Adjusting Devices** — Pot cores with screw type adjusting devices shall be able to withstand the following tests without damage to the core or the adjusting device:

a) A specified force applied in the axial direction to the fixed part of the adjusting device, and

b) A specified torque applied to the adjuster when in the fully screwed-in position.

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*Dimensions of pot cores made of ferromagnetic oxides and associated parts.